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LUNAR ORBITER SELENODESY STUDIES

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1. Analysis of Lunar Orbiter Tracking Data

A file of observational data to be analyzed has been set up as follows:

Lunar Orbiter	a (lunar radii)	e	I	number of days
Ia	1.59	.30	12.1°	6
Ib	1.54	.33	12.3°	21
IIc	1.56	.34	17.6°	25
IIIb	1.55	.33	30.9°	17
IIIc	1.54	.33	21.5°	8
IIIe	1.13	.04	20.9°	20
IVc	2.16	.52	84.4°	19
Vc	1.46	.28	84.6°	20
Vd	1.13	.32	85.1°	20

Solutions are being made for the maximum number of spherical harmonic coefficients of the gravitational field that computer capacity will permit -- at least to 8,8 -- and to restrain ill-conditioning by use of a priori variances.

The orbital theory has been tested extensively against a numerical integration in rectangular coordinates. Some discrepancies involving the analytically calculated short-periodic perturbations have appeared, which may explain the poor results obtained so far. Progress is still slow because of IBM-360 computer difficulties.

2. Reduction & Interpretation of Range-Rate Residuals

The reduction of the accelerations in the direction of the earth inferred by Sjogren & Muller of J.P.L. from Doppler residuals most convenient for geological interpretation would be a set of gravity anomalies at the moon's surface. The gravity anomalies Δg at the surface and the accelerations at the satellite δ_E are relatable through a generalization of what has long been known in physical geodesy as Stokes' Theorem [Heiskanen & Moritz, "Physical Geodesy", 1967, pp. 234-235]:

$$\delta_E = \underset{\sim}{i}_E \cdot \int_\sigma \int \begin{Bmatrix} \partial S(r,\psi)/\partial r \\ -\frac{1}{r}[\partial S(r,\psi)/\partial\psi]\sin\alpha \\ -\frac{1}{r}[\partial S(r,\psi)/\partial\psi]\cos\alpha \end{Bmatrix} \frac{\Delta g R}{4\pi} d\sigma$$

where $\underset{\sim}{i}_E$ is the direction vector of the earth in a moon-fixed reference frame, r is the selenocentric radius of the satellite, ψ,α are the arc distance and azimuth of the point where Δg is given from the subsatellite point, $S(r,\psi)$ is Stokes' Function [see Heiskanen & Moritz], R is the radius of the moon, and the integration is over the unit sphere. What is needed, however, is the inverse of the Stokes equation:

$$\Delta g = \frac{R}{4\pi} \int \int_{\sigma'} Q\left(r,\psi,\psi_E,\Delta\alpha\right)\delta_E \, d\sigma'$$

where the integration is over a surface enclosing the moon defined by the satellite orbits, ψ_E is the arc distance between the sub-satellite and sub-earth points, and $\Delta\alpha$ is the difference in azimuth at the sub-satellite point between the sub-earth point and the anomaly Δg point. Investigations have been undertaken to define the function $Q(r,\psi,\psi_E,\Delta\alpha)$, first in terms of series of spherical harmonics and later, it is hoped, as a closed function analogous to $S(r,\psi)$.

The correlation of the positive anomalies with the circular maria Imbrium, Serenetatis, Crisium, Nectaris, and Humorum is similar to earth experience, where marked positive anomalies are all correlated with areas of recent extrusion: the circum-Pacific belt, plus the Caucasus, Hawaii, the Azores, and Iceland. However, on the earth this correlation is consistent only for very new extrusions: within Quarternary, which is roughly the last million years. Older lava flows, such as the Columbian plateau or the Deccan, are not associated with positive gravity. Hence on the moon either the circular maria are very new, or else the rate of isostatic compensation is much slower. In any case, this time-scale difficulty makes it necessary to consider whether the lava flows which have filled the maria are much more recent than the infall of the bodies which created them.

3. Error Analysis of Laser Ranging to the Moon

Work was continued along the lines described in the last report, but there are no new results to report as yet.

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